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THE VALUE OF THE WORK OF THE SCIENTIST TO HUMANITY.

By JAMES A. YATES, M. S., Normal Training School, Pittsburg, Kan.

Presidential address, delivered at Emporia, November 29, 1907, before the fortieth annual meeting of the Kansas Academy of Science.

I INFER that the high ideals of the Academy demand that in this address some of the broader questions that agitate general scientific thought shall be discussed, rather than some phase of a particular field of investigation. Therefore, I have chosen to speak on the general theme, "The value of the work of the scientist to humanity."

The true test of the value of anything is its utility; that which conserves, strengthens and continues life and growth in its highest and best relations, while its disuse weeds out and destroys. It is not of the monetary value of science that I wish to speak. That it has this side, I will call attention to the statement of our commissioner of education, whose investigations show that in 1800 the total productive capacity of each man, woman and child in the United States amounted to ten cents a day. During the period from 1830 to 1850 the productive capacity rose to thirty cents a day for each inhabitant, while in 1900 it had risen to fifty-five cents a day for each inhabitant. With this data, a very easy arithmetical calculation will show that in a single year the increased production brought about by scientific investigations has returned in dollars and cents many times the amount expended for scientific work during the whole of the nineteenth century. The examples are numerous that show that money invested in scientific inquiry yields almost fabulous returns.

The question of what use will any new truth or fact be, is one that quickly flashes through the mind of the masses. Let us all fully understand that every scientific fact is useful now, or will be in the near or remote future, at least, in helping us to understand and utilize the manifold stores of nature, and therefore has a bearing, either near or remote, on the welfare of man. As each brick or stone is of service in a building, so a place will be found for every truth wrested from nature. The proper measure of value is that of service, and that thing is of greatest value which will help man most in his struggles upward to attain the goal for which he was created.

What have the scientists wrought, when measured by the standard mentioned, that will encourage us to our highest efforts to push forward with stronger determination and greater zeal the work committed to our hands by those who have labored with much success in the past?

Prophecy and revelation are to-day reserved for the scientist, as shown in his work, which involves the gathering of knowledge through observation, its classification, and the deduction of general principles connecting and explaining all the known facts, with the elimination of self, thus establishing the relation among phenomena. It is this kind of work that gives us the profound difference between the work of the nineteenth century and that of all the preceding ones.

One thing of the greatest value which science has taught humanity is the realization and appreciation of its discoveries. In a word, it has given to man a wide, open mind, ready and willing to learn any and all truth, from any and all sources, and to believe that any truth will be strengthened by submitting it to the most rigid and varied tests. It took centuries to convince mankind of the true form and motion of the heavenly bodies, of the great law of gravitation; but only one generation to make the great law of evolution generally accepted.

No one, who has studied the movements of the last century, can fail to be impressed with the large and ever increasing role that modern science has played. Most every phase of our thought and activity has been modified by the new materials introduced, and especially by its changing our viewpoint and our methods of work. Men have ceased to believe that any one man is good authority in every field of inquiry. We have reached a point in advancement where it is necessary to find out what the workers in any particular field say, and upon their conclusions to found our answers to any questions of inquiry in their special line of work. By the work of the scientists of the nineteenth century, every branch of learning and investigation is placed upon an equal footing, and those who would know all the truth must be content with a little knowledge in some one field of investigation, and a faithful reliance upon the workers in other lines for the truth or falsity of any statement in their particular field of work.

The day is past when any one can successfully deny the truth-seeker the divine right of freedom to investigate, to put to the test any and all puzzling questions, and to publish his results. This retrospective study shows us that the scientific stimulus is the hunger to know, and its reverence and yearning are always picketed along the borders of the unknown, pioneering, peering into that wilderness where no one ever trod before, while the scientific spirit lingers behind, a promotor of the good, a strong ally to all that uplifts humanity, by keeping close to the facts and finding the proper relation of cause and effect, while its mission is to eliminate that which is untrue and hurtful, to augment all that is good and true, and to find all the avenues of service.

We sometimes hear of two classes of scientists: Those who give special attention to the discovery of the theories and laws of nature, the finding and study of truth in all its relations for its own sake and the advancement of knowledge; and those who emphasize the application of these facts in the various arts and industries. In a word, pure and applied science, the difference being that of emphasis. However, pure science is the foundation upon which all of its products are built, and of necessity must precede and blaze out the way whereby its applications may continue their activity in every sphere of life, giving to it increased vigor and power. As we glance over the history of man and study the factors that have contributed to his present advanced condition, we cannot fail to be impressed with the part that the various sciences have played. Thus, by its fruits we may measure its value.

We find science, in its applications, lifting burdens from the oppressed, placing man upon a higher plane of life with a greater control of the forces and materials of nature at his command, that he may use them for the betterment of his fellows. Science dignifies all the avocations of life, broadens the scope of man's influence, that he may come in touch with man wherever he may be, removes sectionalism and binds every race and nationality, as it were, into a single community. Mountains, deserts and oceans are no longer barriers between races, while the products of any single clime are familiar to all climes; also cheap and rapid transportation facilities, combined with quick and convenient means of communication, along with sanitary and architectural discoveries and improvements, are relieving our greater centers of congested population and thus lessening all that train of evils. This scientific conquest of nature is one of the strongest allies of the Christian religion. It takes from man the drudgery of muscular labor and allows him to accomplish that which he desires much more successfully, easily, and safely, through the manipulation of the subtle and mighty forces and materials of nature; thereby giving to man a vastly greater opportunity for mental and moral improvement and enjoyment. It has been estimated that the invention of the steam-engine alone has doubled the productive capacity of the world's labor.

Superstition and tradition are the most implacable enemies of science. The cause of their existence is the simple ignorance of the way in which nature works, while a careful and intelligent study of man and his relations, along his present and past environment, will demonstrate to any one, in an incontrovertible way, the reign of law in the universe. That superstition which has made man its most abject slave and has kept him in the depths of ignorance and folly has been largely conquered by the scientists of the past century. However, each age brings new demands, and through the scientific study of nature every one is better fitted to cope with his environment and successfully solve the problems of life as he finds them. Those of the past centuries are interesting as matters of history; while those of the present and future will be solved by men who have learned to look for all the facts and all the causes, and from these combined to make correct conclusions. We plead that this training is very desirable and essential.

In all the discoveries of the past which have been true insights into the future, man saw the correct explanation from the facts of nature actually recorded, showing the unity and simplicity of the apparently unconnected and unassociated phenomena. We expect this to continue and the generalizations of the future to disclose a greater and closer unity in origin and purpose of the phenomena of the universe. Further researches in the minute structure of matter with its various dissociations and combinations, in the molar and molecular forces with the products of their many and varied transformations, will undoubtedly lead to a closer and more fundamental unity among the many scientific lines. May it not be the same force that gives us stereo-isomerism and that holds the planetary systems in their proper relations to all the other systems and to their many respective units. Thus the word and the works supplement each other, and thereby enable us to understand the Author of nature more completely and to realize that the more we know of the material universe the greater will be our appreciation of the mind that formed it.

Science-study disciplines all the faculties of the mind in a healthy and sane way; trains the brain to plan and the hand to execute; furnishes excellent material for logical and philosophical thoughts; supplies literature with live themes, calling for its wisest and most penetrating expressions; teaches a rigid elimination of self from both its data and conclusions, and as great a love for accuracy in statement as in its records.

The growth of scientific study may be seen from the following charts:

Number 1 shows the increase in our agricultural and mechanical colleges, including students and faculties.

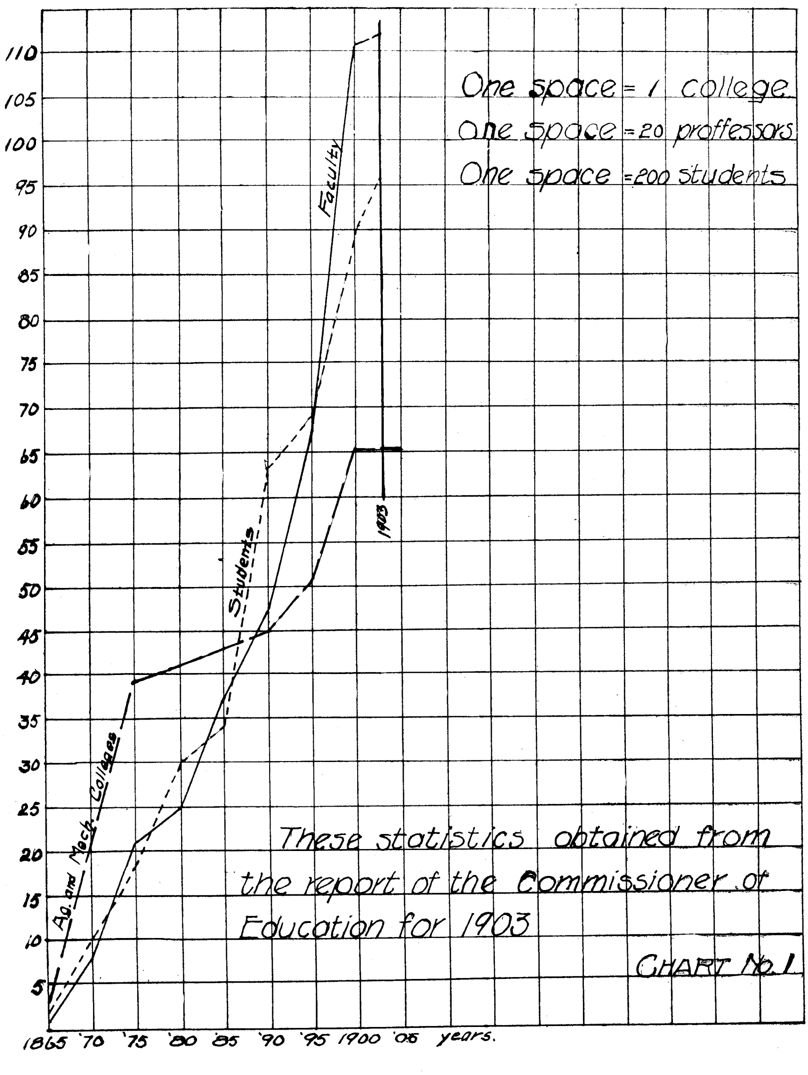
Number 2 shows the increase in the number and the attendance of the manual-training schools of the United States of high-school grade and above. The first school of this character in our country was opened at St. Louis in 1880.

Number 3 shows the growth of all gifts to colleges and universities for endowment, buildings and equipments, also the total gifts which the donor has directed to be used for scientific purposes, including the per cent. of such scientific gifts of all the donations for school purposes. (This data has been obtained from the weekly reports in *Science.*)

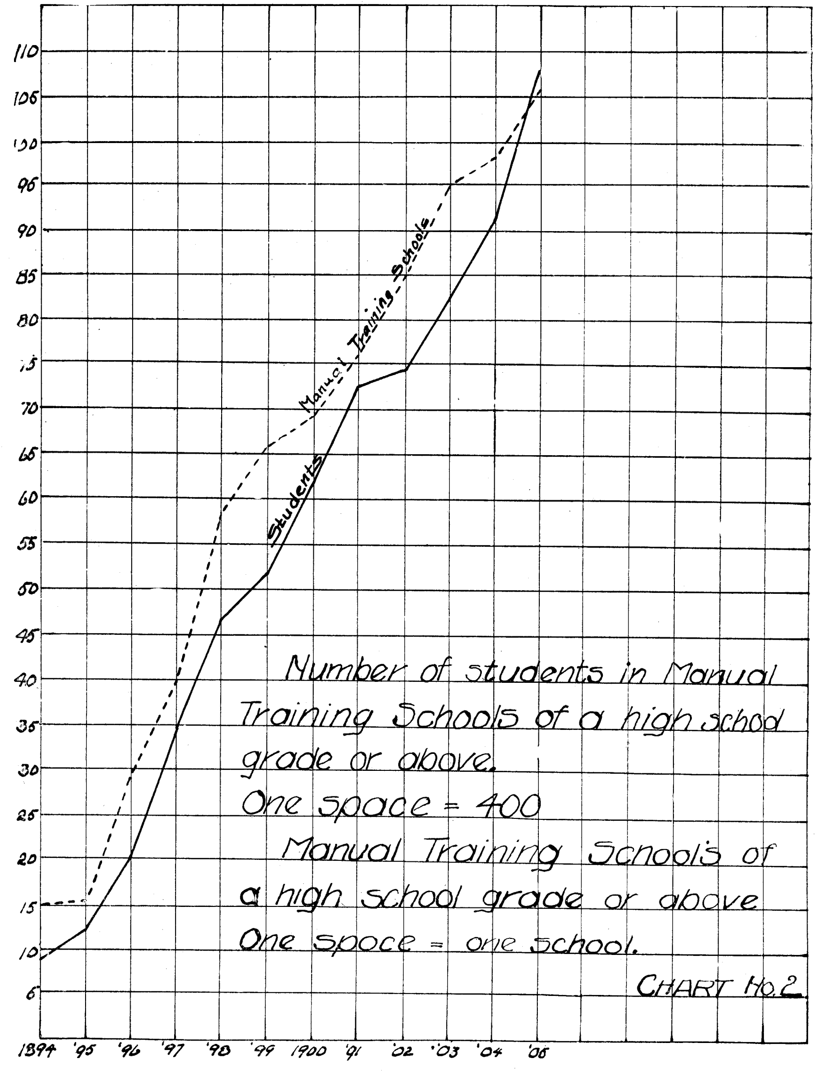
Number 4 shows the per cent. of science teachers of the total faculty of Kansas University and of Ottawa University, the first being a representative state university and the other a representative denominational institution. This shows the average growth of the sciences in the colleges and universities of our country.

During the past nine years, 47.8 per cent. of the total doctorates conferred in our country have been given for work in science. When we call to mind that this represents a measure of the creative scholarship of our country, the value of the work of the scientist is again made evident. The increased appropriations by our government, from $2,038,127, in 1894, to $7,112,690, in 1906, for purely scientific work, shows something of the appreciation in which scientific work is held.

From the reports of the commissioner of education we find



the following ratios between college students and total populations: In 1872, 1 to 1694; in 1902, 1 to 731. Thus, in thirty years the per cent. of those who attend college has more than doubled.. Further, we find in all schools of higher education 1 student to every 337 people. Therefore, the percentage of attendance in our higher institutions of learning has increased more than fivefold in the period mentioned. We may partly realize the value of this growth when we call to mind that a college education multiplies by 400 our chances



of really accomplishing something or value over the one who has only a high-school education. In the secondary schools, in 1892, there was 1 student to 161 inhabitants, and in 1902, 1 student to every 106 inhabitants, an average increase of about nine per cent. for each year. As we study these facts in connection with the changes of the curricula and additions thereto, along with the growth of the faculties of our leading colleges and universities, it seems that the high ideal toward

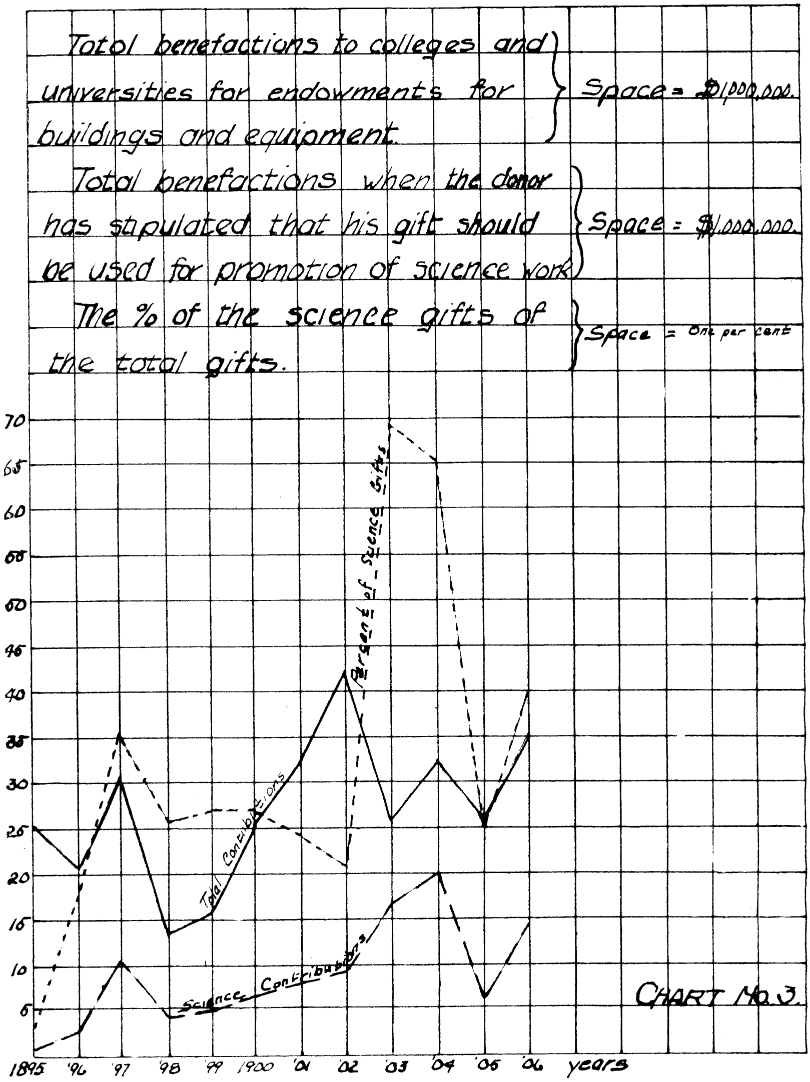
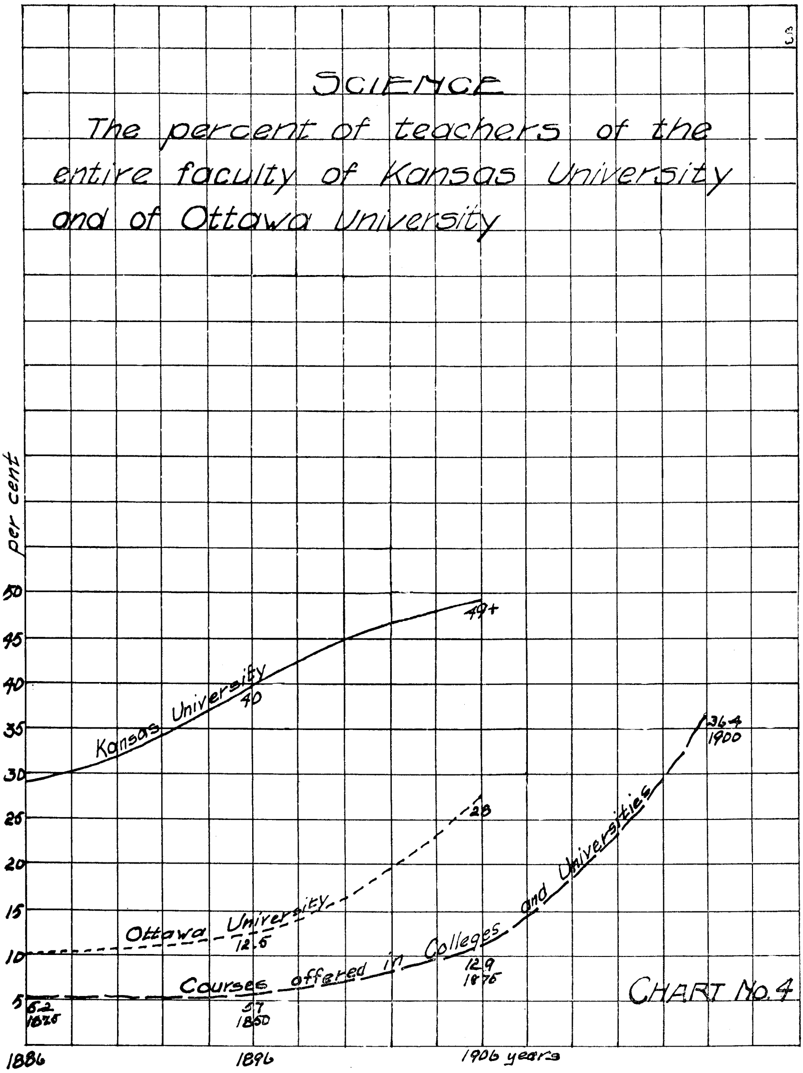


CHART No. 3.

which they are striving is that every upright pursuit in life shall have the highest principles and practices governing it represented in its course of study and taught by the best men it is possible to get, aided by all needed equipment. Further study shows this growth of the sciences has not been in replacing other subjects of the curricula in our various schools. Indeed, every department of all schools has been thereby not only strengthened and increased in efficiency, but it has also



been made possible for a much greater per cent. of the people to obtain a college education by affording a wider scope of work, appealing to all the faculties of the mind, touching every trade and profession of life, and dignifying labor. Believing that the type of mind which designs and builds our various mechanical structures, our magnificent machinery of motive power and labor-saving devices, which serves our every want in such a helpful way, is worthy of the highest cultivation. The true scientist does not seek to replace that which is good, but to make something of service which has not been known or utilized before, as may be seen in many waste products turned into beautiful and useful materials by the magic touch of the chemist. Many barren lands are made to teem, as a great garden, with products to supply a nation's needs, by the skill of the engineer and botanist.

However, let us bear in mind that we have only made a good beginning; that while the past century abounds with brilliant results, the future should grow with increased acceleration; that the facts which are being gathered and recorded will, in the centuries to come, be touched by some genius and thus made to find a place of usefulness. One of the things to be accomplished by the twentieth century, evidently partly realized, is to effectually warn man of the danger of setting any limit to knowledge. When we compare our present with a century ago, and seek for the causes of the great advancement in all our industrial arts, and observe the new and ever widening fields of work, we may get some idea of what the scientists have accomplished.

We may consider some of the important things to be achieved, along with some of the problems yet to be solved. Many of these are of an accumulative character, and broaden as new facts and uses are found. Examples may be given in the changing from a mere hypothesis of one or two of our advanced thinkers to the generally accepted explanation of the many very familiar conceptions of to-day, such as the great age of the earth, the immateriality of heat, the electro-magnetic theory of light, the conservation of energy, and organic evolution. The history of these is sufficient to show how a truth gleaned from facts will widen in its applications and be modified by new facts as it grows.

The way in which scientific discoveries are often made may be illustrated by the discovery of the planet Uranus. The little difference found in the orbit of Neptune, from its calculated orbit at a certain time, enabled the pencil of the mathematician to point within a single degree of the very spot where the planet was found. A similar phenomena enabled Roemer to obtain the velocity of light. One of Jupiter's moons eclipsed a few minutes before, and again a few minutes after its calculated time. This difference, small though it was, enabled the astronomer to show by his calculations that light had a finite velocity. Note these small differences: to any but the scientists a trifle, yet to him whose training has been such as to demand absolute accuracy when his personal equation is accounted for, furnish a line for investigation. The manufacture of nitrogen compounds from the atmosphere by bacteria also illustrates the growth of scientific problems. This one has been attacked by chemists, physicists, and biologists, each with more or less success. Professor Nobbe found that a certain kind of bacteria had the power of causing free nitrogen to combine with other elements, forming nitrates, which compound is a valuable plant-food. Botanists had noticed little tumors on the roots of clover and other leguminous plants, which they had named nodules. It was soon discovered that plants having these nodules would grow in a soil free from nitrogen, while plants devoid of these nodules would not grow in such a soil. This led to an investigation, which found that the nodules were the results of minute bacteria in the soil. Then the problem arose, if these nodules were caused by the soil bacteria, and should not be present in a soil, would it not be possible to supply them, and in this way replenish a worn-out soil and restore it to its original fertility? While this question was pending, Doctor Moore, who had been studying Algæ and had learned something of the properties of these organisms, and who had commenced to apply this knowledge to the purification of polluted water-supplies, was asked by our secretary of agriculture to undertake the solution of the problem of the inoculation of nitrogen in impoverished soil. The problem was finally attacked by the infection of the seed and resulted in some progress, yet the complete solution awaits additional facts, and when all the necessary facts are found the full solution may then be expected.

From the examples mentioned, it may be seen that the methods of planning and conducting a scientific investigation involves finding an exact statement of the problem to be solved, obtaining an accurate knowledge of the work that has been done in this and related fields, and the formation of some definite plan whereby the experimental part is to be faithfully, rigorously and intelligently prosecuted, with the eyes opened and the imagination sharpened to see new relations and applications. When all this is done with the proper foresight in regard to apparatus and material, and the work is pushed vigorously, some results must follow sooner or later.

The value of the work of the scientist may be seen in the changed attitude of the people to-day toward it. In the beginning of the seventeenth century Bruno was burned at the stake for teaching that the earth is not the center of the universe. Early in the eighteenth century Newton was pronounced impious and a heretic for teaching that the law of gravitation extended throughout the universe. In the nineteenth century, how many of our greatest scientists have met much opposition and ridicule. Even to-day, I fear, there are some educators who fail to appreciate its worth, and who ascribe to its workers a lower type of mind, an inferior culture.

Nevertheless, in the study of the history of any of the sciences, we are impressed with the way its truths have grown, though often oppressed by the customary thought of the times. We find in them, as in every historical movement which has had for its purpose the elevation of man, the gradual acceptance of its truths until its acceleration was sufficient to sweep over the errors which opposed it, the opposition only helping to remove the dross which might be clinging to the gold. A further and deeper study reveals the fact that the growth of our knowledge in the truths of the material sphere gives foundation for our political, social and moral improvement. While we contemplate the appropriations of the past years made by our national and state governments, also the philanthropic gifts for stipulated scientific investigations in every line of research, and observe their general appreciation, we cannot fail to be impressed with the fact of their increasingly recognized value.

While the past century has shown wonderful growth, yet when we turn to the future with all our accumulated resources for work, our inheritance of the past, may we not confidently hope that the exercise of the same indomitable energy, courage and intellect that charaterized the scientists of the past will solve, in a much shorter time, the many problems in all the fields of science that bid us a hearty welcome. As we contemplate some of the problems of the future, we find them associated with the past. Charles Darwin's "Origin of Species" gave to biologists the greatest working hypothesis yet suggested. A problem to be completed in the future is the tracing of all the relations of the various classes of animal and plant life; following each of these back to their origin, both in their present and past forms, and from all the facts to complete, in all its parts and details, the tree of life with all its historical relations. Along with this work, our knowledge of the action of certain ions upon the simpler forms of life may be extended, so that we may fully understand all the chemistry of the vital processes, together with the causes of chemical activity in both organic and inorganic substances. The solutions of these problems may give us the full explanation of how the changes in evolution occur, of what necessitates them, and also make clear the laws of heredity. Geologists have mapped in detail, and carefully studied, only a small part of the earth's crust; much basal work of this character remains to be done. The composition of the interior, the mineralogical relations of the rocks, the segregation of the ores, the causes producing great movements of the crust, be they exceedingly slow or rapid, more exact standards for measurement of time, that our conclusions may not be such crude estimates—all these phases of geology present problems which demand solution, both from a theoretical and economical aspect.

We have the vortex ring hypothesis as the explanation of the relation of electricity and magnetism to matter; the conditions of twist in the universal ether for the suspicion by some that all the elements are composed of one primal substance. These are contributions of the nineteenth century, as yet barely a working hypothesis, awaiting the experimental evidence of the twentieth century to confirm, modify, or overthrow them. The nineteenth century gave us the atom, its weight, its laws of combinations, but not its exact form or nature. In fact, the twentieth century has already so far modified our conception of the atom as to leave us only its combining weight.

Experimental evidence proves to us that different ions combine with others in different ratios, but who knows as yet the basal reason for such combinations. Two clear solutions, one of silver nitrate and one of hydrochloric acid, when mixed form a precipitate. A lump of sugar put into a glass of pure water dissolves, a piece of gold does not. A spoonful of salt put into a glass of pure water ionizes, and thus forms an electrolyte; a spoonful of sugar dropped into a similar glass of water goes into solution but does not form an electrolyte

What is the nature of these intermolecular bonds, so easily broken in the one case, so difficult in the other?

By the simple relation of their combining weights, all the elements are arranged in groups composed of those that have similar properties. The twentieth century is awaiting a genius of the type of a Dalton, a Levosier, or a Mendeleeff, to find the fundamental law or laws by which all these facts may be explained. Possibly some light is beginning to appear through the new field of radio-activity, and the electron theory of the structure of matter, which proposes to account for the relation of matter and all forms of energy through whirls and strains in the ether.

Some of the new gaseous elements, as actinium, are said to have a limited life and to change into other substances. Each radio-active product is a transition substance, possessing, while it lasts, definite chemical and physical properties. The electrons that fly off from radium and bombard the air particles around it, and raise the surrounding temperature, are said not to be matter, yet it is found that the mass fluctuates in the presence of the electrical changes. It is further claimed that all the elements possess specific radio-activity in a more or less marked degree. These observations have been made in the last ten years, and would indicate that we may soon fully understand the minute structure of matter and its relation to the ether.

Chemistry as a science is the product of the nineteenth century and has been very fruitful in its service, yet it has many problems of great economic value to solve in such constructive work as the preparation, on a commercial scale, of many compounds, both organic and inorganic.

Physics, with all its brilliant discoveries of the past, presents us machinery of motive power which does not utilize, on the average, more than twenty per cent. of the available energy used. Will the physicist ever be able to turn the latent energy of coal directly into electrical or some other form of kinetic energy without passing through heat, and thus greatly increase the efficiency of our motive machinery? Biologists have shown us how it is possible, by a change in nutrition, to produce aberrant types of life and have demonstrated the transmission of those acquired characters. The investigations of our experimental stations have shown beyond question, how it is possible to add largely to the yield, as well as to the quality, of our manifold farm products. This is accomplished, not by an increase, but by a lessening in the labor involved. Discoveries of incalculable value have been made through the study of the complete life-history of many of our various disease-producing fungi, in both plant and animal life. The means of combatting these injurious parasites has been worked out, in many instances, as well as the prevention and cure of the diseases, in all forms of life, caused from their ravages. However, there are many problems of life yet to be solved, among which may be mentioned the origin of life upon the earth and its many subsequent changes. What are the potentialities of the different primal cells that cause them to develop into widely different organisms? The relation of the chemical and physical changes which take place in the brain and nerves to conscious thought is still incompletely solved.

We trust that the biologists of this century may learn to explain all these difficulties, and that they will give us a basal law governing the vital molecules of the cell and the exact relations in every detail of these molecules to the non-vital ones. We expect the future to reveal the history and present evolutions of man himself; to explain the causes of the different races, their physical characteristics, their mental and moral traits, as are observed in their customs, languages and religion. We hope they will find all the factors that have elevated, also those that have depressed, and show how the one may be augmented and the other retarded: likewise show how the yearning in man for the eternal verities may be increased. The solution of these problems will solve those of our social and governmental evolutions.

Experimental research is adding an increasing accumulation of facts each year in every branch of science. The scope of each is widening and dividing into new fields of investigation. In this way nature is revealing her secrets more rapidly than ever before in the world's history. She is showing her variability and her unity. Therefore, the work is opening new lines of employment and new phases of thought. In this way science is interesting those who supply the sinews of investigation. Yet those who are toiling with all their power that they may find some facts that will aid in the solution of some of the unknown problems of nature are as truly philanthropists as they who contribute of their wealth for the betterment of humanity. Natural laws are inductions from facts and are necessarily successive approximations. They explain the main causes and relations, but many details of all are still to be worked out. The scientists of the nineteenth century have given us these first approximations. No one doubts, in the future investigation of the details and applications, under all conceivable conditions of our present knowledge of nature, but that new truths will be found which will give wider, broader and deeper generalizations.

The trend of the ages, on the whole, has been upward. Our present scientific age is the evolution of the mind which seeks freedom to think, to act for itself, and to be open to the conviction of any truth. Yet it demands facts on which to base its conclusions. The various scientific appliances give the masses time to acquire intellectual and spiritual growth.

A full knowledge and control of nature is man's destiny and one of his greatest needs. To enable our future leaders to comprehend and to perceive perfectly what the knowledge and control of nature is, and how the steps may be increased by which this is gained, is a duty that belongs to each of us. Let our motto be the service of our work to humanity. Let us work shoulder to shoulder with all our powers for greater gifts and larger appropriations, that we may not be hampered for want of means in the investigations of any and all truth, so that we may bequeath to the next century the solution of many of the present unsolved problems, that we may aid in lifting the burdens from the wearied and removing every vestige of prejudice and superstition from the minds of men. This accomplished, and our work will not have been in vain.